What kind of expertise is needed for low energy construction?

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Abstract
Three possible transition pathways to an energy efficient future - market-based, ecological modernisation, and radical transformation – are considered for the construction industry, responsible for 40% of European Union (EU) end-use emissions. Considerable obstacles to achieving low energy construction (LEC) are evident in the UK, and to a greater or lesser extent other EU countries, including: a performance gap between design intention and on-site energy performance; sharp occupational interfaces where the main heat losses occur; declines in the level, breadth and quality of construction vocational education and training (VET); and the lack of a learning infrastructure on sites. Near zero energy building (nZEB) is very different from traditional forms, requiring greater 'thermal literacy' of all construction occupations, higher qualification levels, broader occupational profiles, integrated teamworking rather than self-employment and extended subcontracting chains, and better communication given the complex work processes involved. The required expertise is relative to the transition pathway adopted and in the UK a radical transformation of the existing structure of VET provision and of employment is needed for trainees and the workforce to acquire enhanced understanding of LEC, based on a broader concept of agency and backed up by rigorous enforcement of standards.
Key words: low energy construction, expertise, transition pathways, labour, vocational education and training

Introduction

As much as 80% of greenhouse gas emissions in the European Union (EU) originate from firms' production of goods, suggesting that work sites and processes and chains of production are major polluters (ILO 2011). The construction industry in Europe is especially affected by the need to confront the increasingly rapid warming of the world, not only in terms of employment and the transformation of vocational education and training (VET) systems, but also because the sector as a whole is responsible for 40% of EU end-use CO_2 emissions (Dupressoir 2007). What distinguishes low energy construction (LEC) is the delivery of buildings with extremely low levels of annual energy use (expressed in kWh/m2 per year) in order to meet national and international carbon dioxide emission reduction goals. With core guidance given in three key EU Directives - the Energy Performance of Buildings (EPBD 2010), the Renewable Energy Sources (RES or RED 2009) and the Energy Efficiency Directive (EED 2012) - the EU Roadmap proposes an 80% CO2 reduction in building emissions by 2050 to be achieved through energy-efficient building envelopes supported by renewable/low energy building services (EC 2011a). Technically, LEC demands a fundamentally different approach from conventional construction methods, one that recognises the building envelope as a single thermal unit with renewable technologies and as made up of elements that come together through the interaction of different occupations, including bricklaying, carpentry, tiling and floor laying, insulation, electrical engineering and plumbing.

This study explores the implications of these energy imperatives for expertise in the construction industry. It is largely focussed on the United Kingdom (UK), though similar problems and issues in meeting low energy standards are evident in other European countries and the questions addressed are universal. What kind of transition pathway is best to pursue, given the obstacles to achieving energy efficient construction, and what implications does this have for VET? What does a different, more holistic, approach to the building envelope imply in terms of the VET and qualifications required? And, above all, how is it possible, given the fragmented nature of the construction industry, to achieve the integrated labour process required for these different occupations to work together as a team? Drawing on the work of theorists of education (e.g. Georg Kerschensteiner), sociology (e.g. Richard Biernacki), and economics (e.g. Adam Smith), the study addresses the challenges to the construction industry if low energy targets are to be met and concludes by considering the relativity of construction expertise to the transition pathway pursued.

The transition to low energy construction

There is increasing recognition, particularly following the Stern Review of 2006 that it is necessary to make a social transition in order to improve the environment, employment, qualifications and well-being (ETUC 2004; Steward 2015). Alternative transition pathways have different implications for employment and working conditions and for knowledge and skill development in construction, as well as for the organisation of production and the labour process (Eurofound 2011; CEDEFOP 2013; ETUI 2014; UKERC 2014). For example, one-off short training courses in, for instance, insulation skills will have vastly different consequences for young people and for the labour process compared with comprehensive VET courses for thermal literate insulators. Some transition paths lead towards eco-efficiency, others towards weak ecological modernization and still others towards strong ecological modernization, whilst others move towards more transformative paths. Paul Hampton (2015) has identified three prevalent frameworks in the wider debates on the dynamic of transition to a low carbon economy, each of which implies a different approach to the construction labour process and VET, and hence different kinds of expertise.

The first of these is market based, seeking to avoid state-led investment and promoting strategies focused on adjusting the market context through instruments such as emissions trading, carbon pricing and consumption taxes, as a viable way of easing the cost of transition or a means of creating jobs (Pearce and Markandya 1989). In terms of low energy construction, this means continuing to rely on the premise that skill shortages will be filled by market demand mechanisms, so that, in accordance with Marsden's (1999) 'production' approach, skills are seen as work-based and training dependent to a large extent on the individual employer and on-the-job learning. Such an approach implies that labour is regarded as a commodity, performing recognized activities in the work process under conditions of limited autonomy linked to a specific output, so echoing what Biernacki (1995) terms 'embodied labour' (Clarke et al 2013). This is much the same conception of labour as Adam Smith (1776/1947) espoused, with the worker trained and paid to fulfil particular tasks, broken down into simple steps and overseen by managers, as similarly envisaged by Frederick Winslow Taylor (1911). In relation to construction, it is also identifiable with Ramioul et al's (2016) 'low-road' approach in their study of energy friendly house construction in Belgium, involving high levels of centralised control and specialisation, a lengthy value chain, erosion of team-based working, and poor job quality.

A second and common framework is what has been termed ‘ecological modernization’, which adds to the first framework policies for employment and social justice, training and retraining, learning and skills development and expresses a broadly positive view of the dominant patterns of technological change and economic development in their potential to deliver sustainability, whilst acknowledging that government policy needs proactive investment and promotion and emphasising the need to invest in green jobs and for a ‘just transition’ towards them (Hajer 1995; Mol et al 2009). This framework accords more with Marsden’s (1999) ‘training’ approach, which regards VET as institutionally regulated, related to a person’s ability and certified qualifications, and generally collectively and industrially organised. The labour implied is no longer a commodity but has a mind of its own, though as an agent remains restricted by the institutional setting or structure. This second approach is close to Ramioul et al’s (2016) ‘high road’, which – compared to their ‘low road - is more employee-centred, with greater worker participation, empowered teamwork, investments in skills of the workers, and better job quality.

A third framework identified is more radical, suggesting that radical transformation of social and technological arrangements through a coalition of societal actors and stakeholders will be needed to ensure a transition to a low carbon society (Grin et al 2010). According to this ‘radical transition’ approach, to achieve the necessary carbon reductions will require integrated and publicly-owned energy supply, natural resources and transport systems, ‘socially/ environmentally useful production’ and/or ‘extended producer responsibility’. The approach implies that, through the development of personal capabilities and occupational capacity, labour - or in Biernacki’s (1995) terminology ‘labour power’ - becomes a more active agent with real autonomy to challenge the institutional structures of VET and employment and to champion the reduction in carbon emissions, for instance in the UK through green representatives (Snell and Fairbrother 2010).

This sociotechnical transitions framework therefore raises the wider issue of workers as environmental actors or innovators (Räthzel and Uzzell 2013; Eurofound 2011). The VET system required to achieve this needs to be broader, akin to that advocated by Georg Kerschensteiner, which advocates developing the civic virtues of the worker and consciousness of the impact of occupational activities both on other occupations and on society. The consequence of such a system should be to help to equip labour with the potential to challenge structures through the knowledge, skills and competences (KSC) acquired and the expertise to innovate (Winch 2006). It is no longer a system geared only to developing skills but one associated with a broader concept of agency, developing the intellectual and manual capabilities necessary to act autonomously and to plan and manage new and complex processes (Winch 2013). This third orientation indicates the need for interventions in the construction process that are not simply reactive in terms of justice or job protection, but proactively intervene to shape the nature of the green transition. It concurs with Markey et al’s (2015) findings that a high degree of substantive – broad and deep –

employee participation, with employees and unions providing an important impetus for action, can most effectively reduce carbon emissions.

Problems with low energy construction

Which of these different transition pathways is needed in order to develop appropriate expertise for an energy efficient construction? Many countries have embarked on LEC programmes, including developing ultra-low standards such as the Canadian R2000, the Swiss Minergie, the Code for Sustainable Homes Level 6 in the UK, and the German Passivhaus. However, though the imposition of stringent control measures through building regulations should mean that new buildings achieve higher energy efficiency than previously, research has documented a so-called 'gap' between the design and building performance of both low energy new buildings and retrofits, between what might be regarded as application of the design or engineering concept to the reality of the building process (Johnston, et al. 2010). As-built performance rests on whether the design elements are possible to construct under site conditions, along with important considerations concerning the competence, know-how and knowledge of building workers or what might be termed their 'energy' or 'thermal literacy'.

Measuring energy performance, whilst not an exact science, is a relatively new experience in the UK construction sector, driven by the need to evidence the reduction of carbon dioxide emissions. Three test procedures - air permeability; coheating; and thermal imaging – can be used to assess the pre-occupancy thermal performance of the building envelope (floor, walls/doors, windows and roof). Through these techniques, it is possible to make a reasonable assessment of the building envelope's 'as-built' heat loss and compare the designed heat loss with that of its performance without the additional complication of normalising for occupancy. Air permeability testing has shown that the UK maximum air leakage rate - at $10m^3/m^2.h$ at 50Pa - is about ten times that of the European Passivhaus low energy standard (Johnston and Miles-Shenton, 2009; Shattock, 2012). The need to remedy this performance gap is, therefore, crucial to meeting UK low carbon targets, as laid down in the Climate Change Act of 2008 and by the European Union Directives.

The social relations involved in the construction process, as well as its organisation, are central to understanding the difference between the energy loss envisaged and the actual building performance. They imply a focus not only on how labour is organised and employed but also on the quality of the labour involved, including the qualifications of building workers and the VET system in place. This has been recognised by the European Commission in its *Energy Efficiency Plan 2011* (EC 2011b), which specifically addresses the need for qualified workers, the lack of appropriate training for architects, engineers, auditors, craftsmen, technicians and installers, notably for those involved in refurbishment, and the requirement for 'new skills' and 'environment-conscious' VET in construction and for adapting 'curricula to reflect the new qualification needs ' in order to 'transition to energy-efficient technologies' (p.7). To facilitate this transition, the EU has supported an audit of labour availability through the *Build-up Skills* initiative, with National Reports leading to National Roadmaps, which should integrate into the broader EU employment and qualification strategy and are focussed on social rather than purely technical obstacles, especially with regards to upskilling the existing workforce through continuing training. These have shown that VET for LEC poses particular challenges not only because of its technical demands but also because of the complexity of process management and co-ordination, particularly the cross-occupational co-ordination required. The Build-up Skills overview report notes 'weaknesses of national education and training systems' and a 'shortage of cross-trade knowledge and skills (e.g. installation of few RES systems), including insufficient coordination between occupations and their 'borderline' skills and unsatisfactory interdisciplinary training opportunities within upper secondary and continuing education and training systems' (EC 2014: 64-5). The German *Build up Skills* report in particular locates the main problem in reducing emissions in: 'interfaces between trades' and 'lack of any understanding for a house/building as one integrated system' (Build Up Skills 2012: 6-7). The suggestion is that energy requirements can only be met by overcoming obstacles that lie in the VET system (achieving broad and comprehensive know-how) and the building production process (bridging trade interfaces). Yet studies across Europe indicate a lack of thermal and energy literacy and a growing need for transversal abilities within those areas critical to achieving energy efficiency (Zero Carbon Hub 2014).

The imperatives for low energy construction to meet EU 20/20/20 targets thus introduce new VET requirements presenting a major challenge to European countries, including: greater educational input to achieve thermal literacy for all workers concerned; broader qualification profiles to overcome interfaces between the activities of different occupations where the main heat losses occur; learning from feedback; and integrated team working and communication given the complex work processes involved. Sealing and insulating the building envelope is critical to achieving energy efficiency given that air leakages in, for instance, a house typically occur through the interfaces between the roof and walls and between the windows and doors and walls. These interfaces are at the same time between those employed in different occupations, between, for instance the roofer, carpenter, bricklayer, and groundworker. And these occupational interfaces are not just socially but contractually divided, coming usually – at least in Britain - under separate subcontracts. The methods deployed by the builder also need to encompass the supply chain since any change in the quality of components, either because those specified are not available or from a value engineering perspective, will impact on the final energy demand. This suggests a major transformation of the current fragmented labour process, characterised in the UK at least (though perhaps to a lesser extent in some other European countries), by extensive subcontracting, the use of agency labour and the self-employed, widespread non-formal on-the-job learning, high labour mobility, exclusively white male social networks and a sharp separation between operatives and professionals.

Problems with developing VET for LEC in Britain (VET4LEC)

LEC requires a highly qualified workforce, whether for retrofitting or new build, with knowledge of building physics, mathematics, engineering or material behaviour, as well as more abstract competences such as reading off drawings, setting out, bridging interfaces and constructing to high precision. The low level of skills and qualifications of many employed in the industry in Britain and the lack of initial and further training are detrimental to low energy performance, just as are the increasingly high numbers of those self-employed and employed by agencies. In 20013/14 nearly half of the total construction workforce of two million came under the special Construction Industry Scheme (CIS) for self-employed workers (UCATT

2015). At the same time, the number of first year trainees and apprentices has plummeted since 2007, with those in the wood trades falling from 13,743 to 4536 by 2015, in bricklaying from about 9,000 to 2364, and in plant operation from 4,747 to just 834 (ConstructionSkills 2015). Overall in ten years construction 'craft' training has collapsed, from first year trainees numbering 38,447 in 2005 to a historical low of 11,586 in 2015, only 35% of whom were undertaking work-based training and only 3,000 an apprenticeship programme. Most training provision too continues to be concentrated in the traditional trade areas, covering an ever-narrower scope of activities. About three-quarters of apprenticeships are in the four main building trades – wood, bricklaying, painting & decorating, and plastering & dry lining, though these constitute little more than half of the forecast requirement for skilled manual trades. In addition, the vast majority of construction trainees only achieve National Vocational Qualification (NVQ) Level 2, a qualification far lower than that typical for skilled construction workers in other leading European countries and too low to then progress to supervisory or managerial levels (Brockmann et al 2010).

In this situation, it is not surprising that few builders in UK take responsibility for training: 73% of construction companies have been found to have no training plan, 81% have no training budget and only 19% invest in training (BIS 2013). This is understandable in the light of the high levels of self-employment and the fragmentation of firms and degree of subcontracting in the industry. It is, however, that much more serious given the employer-led nature of the VET system, where trainees depend on employer goodwill to acquire work experience, qualifications and VET (including for green construction), where lobbying by employer trade associations is critical to new qualifications being developed, and where government policy is focussed on work-based apprenticeship.

Table 1: Thermal skills required for different building elements

Envelope Element	**VET role**	**Thermal Skills required**
Ground floor slab	No formal VET. Site experience by general labourer	Horizontal insulation of the slab with vertical insulation to prevent thermal bridging at perimeter
Walls	Bricklaying NVQ levels 2 and 3	Cavity wall insulation. Insulation must be butted together and be complete at corners and breaks in the wall. Air circulation behind or through insulation significantly reduces its impact. Bricklayers need to understand the role of thermal bridging. There is no mention of air tightness or thermal bridges in NVQ levels 2 and 3.
Openings (windows & doors)	Level 2 NVQ Diploma in Fenestration Installation required for UK Government sponsored 'Green Deal'. Otherwise there is no formal VET and these are fitted by many occupations including bricklayers, carpenters, general builders, specialist window fitters.	No formal VET in window fitting. It is traditionally the role of the carpenter but with newer materials, such as PVC, aluminium and specialist glazing those carrying out the fitting vary from the general building labourer to the window supplier. This is central to air tightness programme since windows fill a hole in the wall.
Loft insulation	Insulation installer NVQ level 2 required for 'Green Deal'. Otherwise no formal VET.	No formal VET in insulation. Six separate NVQs at Level 2 were developed for the Green Deal in 'Insulation & Building Treatments'.
Plastering	Generally Plastering NVQ level 2	The wet plaster seals the envelope to act as the 'air barrier'. No mention of air tightness in the NVQ level 2.
Builders openings	Various/bricklayer/labourer. Often no formal VET.	Holes in envelope for services (water, drainage, etc.) break into the 'air barrier'

Source: CITB Qualification Details. For example: Level 2 Diploma in Bricklaying DIP 102/2, Level 2 Diploma in Plastering, etc. Revised March 2009.

The example of new build traditional masonry well illustrates the extent to which construction qualifications in Britain incorporate or are sensitive to low energy requirements. Labour requirements for the dwelling envelope relate to solid ground floor slabs, cavity brick walls and timber roofs and Table 1 reveals the extent to which these areas are carried out by those with 'skilled' and 'advanced skill' qualifications, as well as those operations where there is no formal training available, including 'groundworks' (e.g. digging foundations, laying drains and, paving slabs) and concreting. For those areas with formal training, whilst 'insulation and energy efficiency' is referred to in NVQ Level 2 and 3 documents for bricklaying, site carpentry and plastering, this is treated as an element in a range of 'knowledge' issues and therefore of equal importance to other areas within 'knowledge of building methods and construction technology'. There is no knowledge requirement to understand the envelope as a single system, no reference to air barriers, air tightness or thermal bridging, no requirement to understand the interplay between the separate envelope workers and final energy performance, and no celebration of the 'thermal literacy' of the construction worker so central to achieving a low carbon future. Where formal VET exists, analysis of the training content for new entrants to the industry identifies a lack of focus on low energy as a key performance objective.

The examples given in Table 1, coupled with the declining levels of training, suggest that the third transition pathway, radical transformation of social and technological arrangements, rather than the incremental improvements of the first and second pathways, is appropriate. This implies a transformation of VET away from narrow, low level task-based training towards a system more akin to that proposed by Kerschensteiner, with a wide occupational scope, encompassing also 'civic virtues' and a high level of technical and manual expertise (Winch 2006).

What kind of VET for LEC in Britain?

Traditionally, VET in Britain has relied on the development of narrow trade-based skills geared to particular employer needs, and focussed on producing pre-defined outputs (Clarke et al 2013). Increasingly the system has become work-based, with a built-in assumption that learning depends on induction, on the generalisation of a range of practical experiences (Clarke and Winch 2004). However, the KSC required for much low energy construction work cannot be directly read from experience or site observations. Nor, given the contractual divisions between the different trades or occupations, is it possible to observe or experience the real problems associated with bridging interfaces between them. These are not manual skills but more abstract competences, requiring a model of learning revolving around the application of relevant theories and instances of theoretical propositions to practical situations, and thus depending on deductively relating general principles to particular circumstances. This in turn suggests a higher level of qualification, as proposed in the Richard Review of Apprenticeships in 2012, which recommended far-reaching changes to the way in which VET is conducted in England and a minimum Level 3 qualification. A qualification at Level 3 is necessary for effective LEC because the abilities required range beyond a narrow band of technical skills and encompass heightened technical understanding of the technologies employed, together with process knowledge of the project and the ability to communicate, co-ordinate and evaluate elements of the process with other occupations.

As apparent from Table 1, broader occupational profiles and at the same time integrated teamwork are also required, as each occupation must understand its role in the process and 'buy-in' to the project. Since the joint efforts of several occupations are needed to meet energy standards for the successful completion of the project, an understanding of the work of several occupations will be necessary. With the envelope air tightness standard, for example, an initial target, a method statement, is required for all types of buildings, and then each occupation has to realise its role in creating an envelope that meets the design specification. For the masonry build, bricklayers, plasterers, window fitters and plumbers (more generally, service entries – what are known as 'builders openings') are involved. Another example of where cross-occupational knowledge is needed is insulation completeness plus the 'thermal bridges' that occur at all junctions and openings such as at lintels; bricklayers, floor layers, and roofers are all involved and need to co-ordinate their work. Envelope insulation needs to be continuous, the building must exclude draughts and meet an air tightness specification, and this involves all elements of the envelope and raises technical specification by an order of magnitude with detailed treatment of thermal bridges, builders' openings, sealing windows and ensuring appropriate air tightness at all junctions between floors, walls and roof to meet the target 'fabric energy efficiency'.

To ensure thermal comfort and public health, the building then requires space heating and/or cooling, domestic hot water and lighting. Provided the fabric energy efficiency has been met, reducing heating and cooling needs to the absolute minimum, the selection of heating and cooling appliances demands attention to their product efficiency, their fuel or power source and emissions. New low and zero carbon technologies that replace boilers with heat pumps, micro-combined heat and power, solar thermal (solar hot water) provide the opportunity to offset emissions through the generation of renewable power (electricity) and/or renewable heat. However, unlike boilers, heat pump performance is particularly sensitive to poor design, installation and operation and successful installation requires understanding quality engineering design and all the problems associated with the handover to the user (e.g. commissioning, controls setting and ability to explain these) (Gleeson, 2015). For most buildings integrated renewable generation will entail photovoltaics and/or solar thermal installations where renewable output is deemed as 'off-setting' and provides net zero or nearly zero emission buildings.

All built environment occupations need enhanced VET and increased occupational scope for near zero energy building (nZEB) to succeed, so that workers can carry out a wider range of operations relevant to LEC than is currently the case with, for instance, the narrowly trained English bricklayer (Brockmann et al 2013). LEC workers need to understand and evaluate the principles of LEC, including the technologies employed and how these work within a low energy building, as well as the conditions for the successful execution of a LEC project and the principal factors that can cause it go wrong. Their curriculum needs to embrace the principles concerning why certain activities are carried out in the way and the sequence in which they are carried out, as well as how such principles are realised in practice, appreciation of which can be taught in relation to some observational work on site.

Conclusions

Ultimately the concern for all should be that carbon dioxide reduction targets will be missed due to inadequacies in the VET and qualification systems and the organisation of the production process. For these obstacles to be overcome, it is essential not only to appreciate the role and value of labour but also to involve the workforce in transforming the VET system and the labour process for a low carbon future. For LEC to succeed, it is vitally important for each occupation to know what the other is doing, but the integrated teamwork needed to prevent energy loss requires a less extensive subcontracting chain and more direct employment if the different occupations are to work more closely together and a learning infrastructure is to exist. In terms of expertise, an extensive initial and continuing VET programme is needed to enhance KSC, based on broad occupational profiles and careful attention to the application of theoretical propositions. These requirements for LEC imply a radical transformation of both the structure of the industry and the VET system, to be achieved by enhancing the role of labour as an agent of production. They also suggest that the nature of expertise is relative to the transition pathway adopted.

References

Biernacki, R. (1995) *The Fabrication of Labour: Germany and Britain 1640-1914.* California Press, Berkeley.

BIS (2013) *UK Construction, an economic analysis for the sector,* Department for Business, Innovation and Skills, London.

Brockmann, M. Clarke L. and Winch C. (2010) *Bricklaying is more than Flemish bond: bricklaying qualifications in Europe),* European Institute of Construction Labour Research (CLR), Brussels

Brockmann, M., Clarke, L., Hanf, G., Méhaut, P., Westerhuis, A., Winch, C. (2011) *Knowledge, Skills, Competence in the European Labour Market: What's in a Vocational Qualification?,* Routledge, Oxford

Build up Skills (2012) *Vocational education and training for building sector workers in the fields of energy efficiency and renewable3 energy,* German report by Peter Weiss, Richard Rehbold and Elisa Majewski, Intelligent Energy Europe, September

CEDEFOP (2013), *Skills for Green Jobs: European Synthesis Report*, Thessaloniki

Clarke L., Winch C. and Brockmann M. (2013) Trade-based skills versus Occupational Capacity: the example of bricklaying in Europe, *Work, Employment and Society,* December, 27(6), 932-951

Clarke, Linda and Christopher Winch (2004) Apprenticeship and Applied Theoretical Knowledge, in *Educational Philosophy and* Theory, 36/5, November, 509-521

ConstructionSkills (2015) *Training and the Built Environment 2014,* CITB, Bircham Newton.

Dupressoir S. (2008) *Climate Change and Employment: Impact on employment in the European Unon-25 of climate change and CO2 emission reduction measures by 2030,* European Trade Union Institute, Brussels

ETUC (2004) *Climate change – avenues for trade union action*, European Trade Union Confederation, Brussels

ETUI (2014), *Climate Change: implications for employment*, European Trade Union Institute, Brussels

Eurofound (2011) *Industrial Relations and sustainability: the role of social partners in the transition to a green economy*. Dublin

European Commission (EC) (2011a) *A Roadmap for moving to a competitive low carbon economy in 2050*, Brussels

European Commission (EC) (2011b) *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and The Committee of the Regions: Energy Efficiency Plan 2011*, Brussels

European Commission (EC) (2014) *Build-up Skills: EU Overview Report, Staff Working Document,* Intelligent Energy Europe, European Union

Gleeson C. (2015) Residential heat pump installations: the role of vocational education and training, in *Building Research and Information,* 11 September

Grin J., Jan Rotmans, Johan Schot (eds) (2010) *Transitions to Sustainable Development, New Directions in the Study of Long Term Transformative Change*, Routledge, London and New York

Hampton P. (2015) *Workers and Trade Unions for Climate Solidarity: tackling climate change in a neoliberal world,* Routledge, London and New York

Hajer M. (1995) *The Politics of Environmental Discourse: Ecological Modernization and the Policy Process,* Oxford University Press

International Labour Organization (ILO) (2011) *Towards a Greener Economy: the social dimensions,* International Institute for Labour Studies IISL, 116 p.

Johnston, D. and Miles-Shenton, D. (2009) Airtightness of UK dwellings. *In:* Dainty, A.R.J. (Ed) *Procs 25th Annual ARCOM Conference,* 7-9 September 2009, Nottingham, UK, Association of Researchers in Construction Management, 271-80.

Johnston, D, Wingfield, J, Miles-Shenton, D. (2010) *Measuring the fabric performance of UK dwellings*, Proceedings of the Association of Researchers in Construction Management (ARCOM) Twenty-Sixth Annual Conference, 6-8 September

Markey R., McIvor J. and Wright C.F. (2015) Employee participation and carbon emissions reduction in Australian workplaces, *The International Journal of Human Resource Management,* published online June.

Marsden, D. (1999) *Theory of Employment Systems: microfoundations of societal diversity*. Oxford University Press, Oxford.

Mol, A.P.J., Sonnenfeld, D.A., and Spaargaren, G., (eds.) (2009) *The Ecological Modernisation Reader: Environmental Reform in Theory and Practice*, Routledge, London and New York

Pearce DW and Anil Markandya (1989) *Blueprint for a Green Economy,* Earthscan

Räthzel, Nora und David L. Uzzell (2013) *Trade unions in the Green Economy,* Routledge, London and New York

Ramioul M. Benders J. van Peteghem J. (2016) 'Green construction and team design: low road and high road teams to build energy-friendly houses', *World Review of Entrepreneurship, Management and Sustainable Development,* Vol 12, No. 1, pp 33-49

Richard D. (2012) *The Richard Review of Apprenticeship,* November, School for Startups, London

Shattock, Z. (2012) *Can the air pressure testing regime be improved to mitigate problems of policy and process,* Unpublished dissertation, University of Westminster

Smith, A. (1776/1947) *Wealth of Nations.* Volume 1. Everyman's Library, London

Snell, D & P. Fairbrother (2010) Unions as Environmental actors, *Transfer* 16(3) 411-424

Stern, Nicolas. (2006) *Stern Review Report on the Economics of Climate Change*. HM Treasury, Cabinet Office, London

Steward F. (2015) *Policies and practices to promote work enhancing pathways in the transition to a low carbon economy*, ACW International Policy Working Group Report, Policy Studies Institute, London

Taylor F.W. (1911) *The Principles of Scientific Management,* reprinted by Lightning Source UK Ltd.

UCATT (2015) *Sharp growth in false self-employment in construction,* Press statement 13 January, Union of Construction, Allied Trades and Technicians

UKERC (2014) *Low carbon jobs: The evidence for net job creation from policy support for energy efficiency and renewable energy,* by Blythe, W, Gross, R, Speirs, S, Nicholls, J, Dorgan, A and Hughes, N, UK Energy Research Centre, London

Winch C. (2006) 'Georg Kerschensteiner – founding the dual system in Germany', *Oxford Review of Education,* Vol. 32, No 3, July, pp. 381-396

Winch Cl (2013) Education and Broad Concepts of Agency, *Educational Philosophy and Theory,* 45 (12), 1205-1218

Zero Carbon Hub (2014) *Closing the gap between design and as-built performance.* Evidence Review Report, Zero Carbon Hub, London